MODULE 12
FORECAST MODELS

OBJECTIVES

At the end of this module, the student should be able to**:**

1)   Understand the concept of numerical modeling and its output of forecast models
2)   Understand the methodology, process, and importance of choosing a particular model run

With the advent of computers and the increase in their capabilities, the science of meteorology has evolved to the point of computers being able to give us pictures of weather scenarios up to 240 hours in advance. The branch of meteorology known as numerical modeling has developed several atmospheric models with which meteorologists can forecast weather events.

In previous modules, we examined and analyzed surface and upper air charts. These maps told us what was occurring at observation time regarding winds, temperature, and moisture. Then we looked at satellite and sounding information for more clues about the overall weather picture. All of this information helped us produce a snapshot of what had happened in the past or what was happening currently. This is certainly valuable information for meteorologists, but we still need a variety of tools to take us from the present to the future, to predict the weather.

In numerical modeling, scientists use mathematical equations to derive numerical quantities for heat exchange, atmospheric lift, moisture, and pressure fields. It is important to note that all of these mathematical models begin their calculations with data collected from the same upper air soundings and surface observations we studied in previous modules. You can see the importance of these very basic information sources. In other words, garbage in (bad data) means garbage out (bad model forecasts).

There are several different forecast models which are produced daily by the Hydrometeorological Prediction Center (HPC). When forecasters discuss models, you will often hear the terms **NGM** (Nested Grid Model), **ETA** (Eta Forecast Model), or **AVN** (Aviation Model). The reason for the variety of models is the nature of meteorology itself. The science of weather and the atmosphere is inexact. To put it bluntly, we are not 100 % sure how the atmosphere behaves. We have best guesses and hypotheses but very few concepts are concrete and exact. This is where the numerical modelers help out. They develop algorithms and equations based on physics and observations in an effort to represent, as closely as possible, the behaviour of the atmosphere.

In numerical modeling, all of the properties of the atmosphere are broken down into 7 fundamental equations, called the **primitive equations**. If we could solve these equations for all times and all points in the atmosphere, weather forecasting would be an easy and exact process. However, even with the most powerful supercomputers, it would take several days' processing time to produce a one-day forecast. Obviously, this isn't very practical. In order to speed up the

computing time, numerical models use various approximations and assumptions. Rather than doing calculations for every point in the atmosphere, they may calculate one point every 40 miles in the north-south and east-west directions. They may compute values at only 20 or 30 vertical levels in the atmosphere. Models utilize approximations of the primitive equations which are easier to solve on a computer. Each of the different types of forecast models uses different assumptions and approximations; thus, each model will have a slightly different forecast solution.

The output from computer models is given to us in a familiar form. Remember the contour analyses we did at various levels in the atmosphere? They allowed us to get a three-dimensional look at how the atmosphere was behaving at the time of the observations. Computer model output can be represented on the same type of contour maps. Figures 12-1 and 12-2 show a forecast 500 mb and sea-level pressure chart, respectively. Note the similarity to our earlier contour analyses. Model data may also be presented in a four-panel format, allowing meteorologists to view different forecasts side by side (Figure 12-3).

MODEL VERIFICATION

As indicated earlier, different forecast models will often have different answers to the same forecast problem. So how do we know which model to use? Forecasters over the years have developed a methodology to see which model forecast they should use as guidance. This methodology consists of :

1) Model comparison,
2) Surface and upper air map analysis,
3) Comparison of model initialization to respective surface and upper air maps, satellite data and upper air soundings,
4) Run-to-run consistency, and
5) Known model biases.

Suppose you are a forecaster at Amarillo, Texas and have been briefed by the previous forecaster that the model run which came in on her shift indicated a possible severe weather outbreak in 36 hours. It is your responsibility to design a complete forecast package assessing the threat for severe weather and the need for early notification should the threat be real.

Later in your shift, two model runs arrive from HPC along with numerical guidance for temperatures, precipitation, cloudiness, and other parameters. Model I has an upper level trough entering New Mexico by 36 hours with a surface low in the Texas panhandle. Model II has the surface low in deep south Texas by 36 hours with the upper level trough swinging into central Texas. Now you have a problem. The positioning of the features in Model I have severe weather targeted for the Texas panhandle, while Model II suggests all of the activity will be in south Texas.

You know that the timing of the features depends on the input to the model run. You have access to the latest surface map and upper air maps from the most recent upper air releases. You also have satellite pictures available which help to pinpoint weather features and trends. We analyze

the surface and upper air maps as we did in earlier modules and look at the various satellite loops. From this you find that the initialization for Model II has the upper level jet and an upper level low pressure area farther south than its actual observed position. Looking at the initialization panel for Model I, you see that the pressure centers, jet streams, and surface features are more representative of actual conditions. Thus, Model I seems to have had better data from which to start its forecast.

The final check should be your knowledge of model preferences or biases. These are present in every model due to the fundamental equations on which the model is developed. Many forecasters are familiar with these biases. They often give them a forecasting advantage over the model. For example, some models are slow in moving strong cold fronts. If you knew this, you would forecast a front to move faster than the model forecast. This would allow for improvement over the model for temperature, precipitation, and cloud forecasts. For the Amarillo example, you may be aware that Model II often takes strong upper level troughs farther south than they actually track. Knowing this you would be swayed to go with the Model I track of the upper level trough swinging through Colorado.

Clearly, forecast models have enabled meteorologists to make timelier and more accurate forecasts. It must be remembered that the forecast models are only approximations, and that there are limitations and biases to the models' capabilities. However, the combination of computer model output and an experienced forecaster's interpretation of that model often leads to very accurate forecasts in the 1- to 2-day time frame.
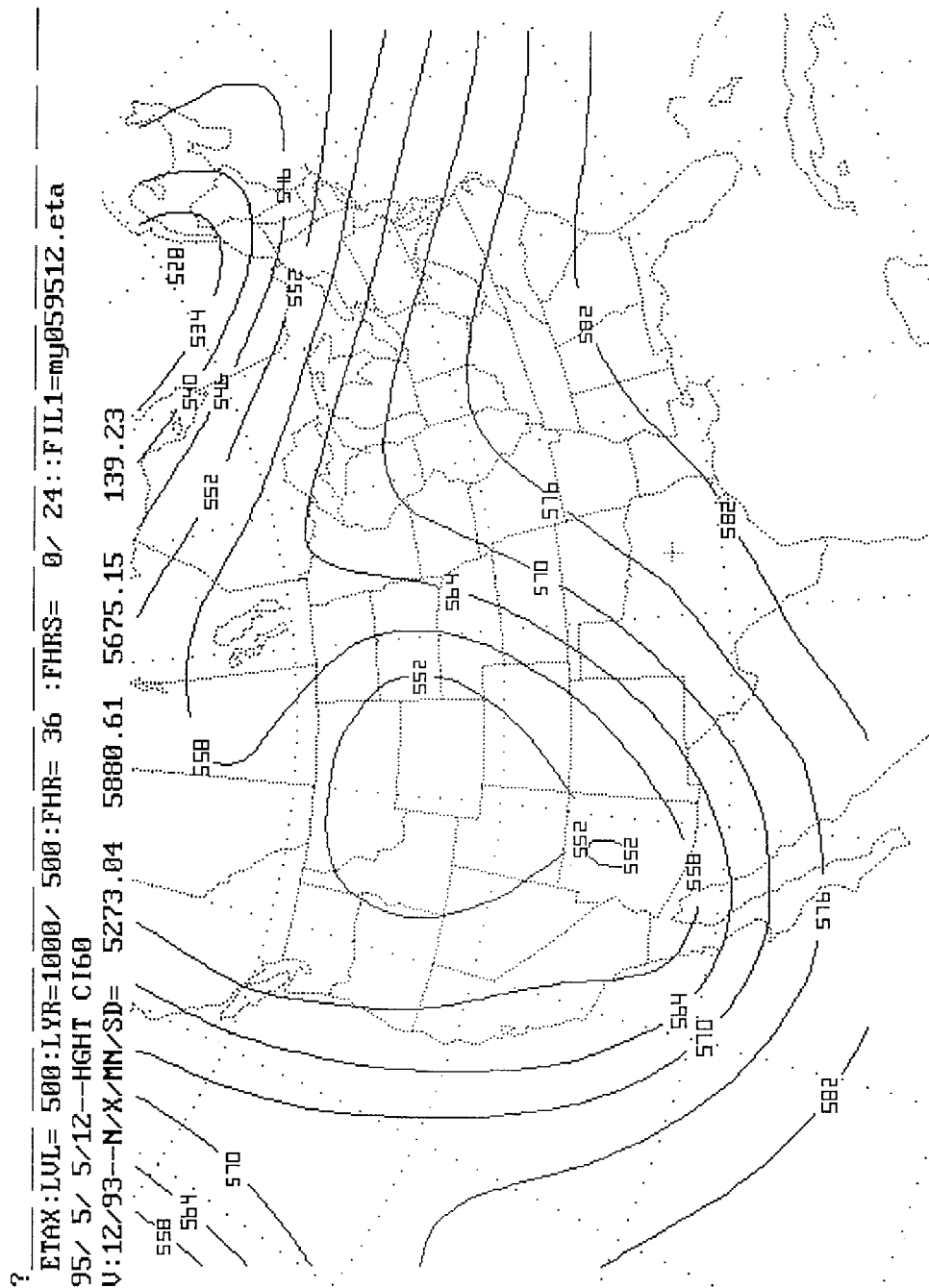
Figure 12-1: 36-hour 500 millibar height forecast from the ETA forecast model.
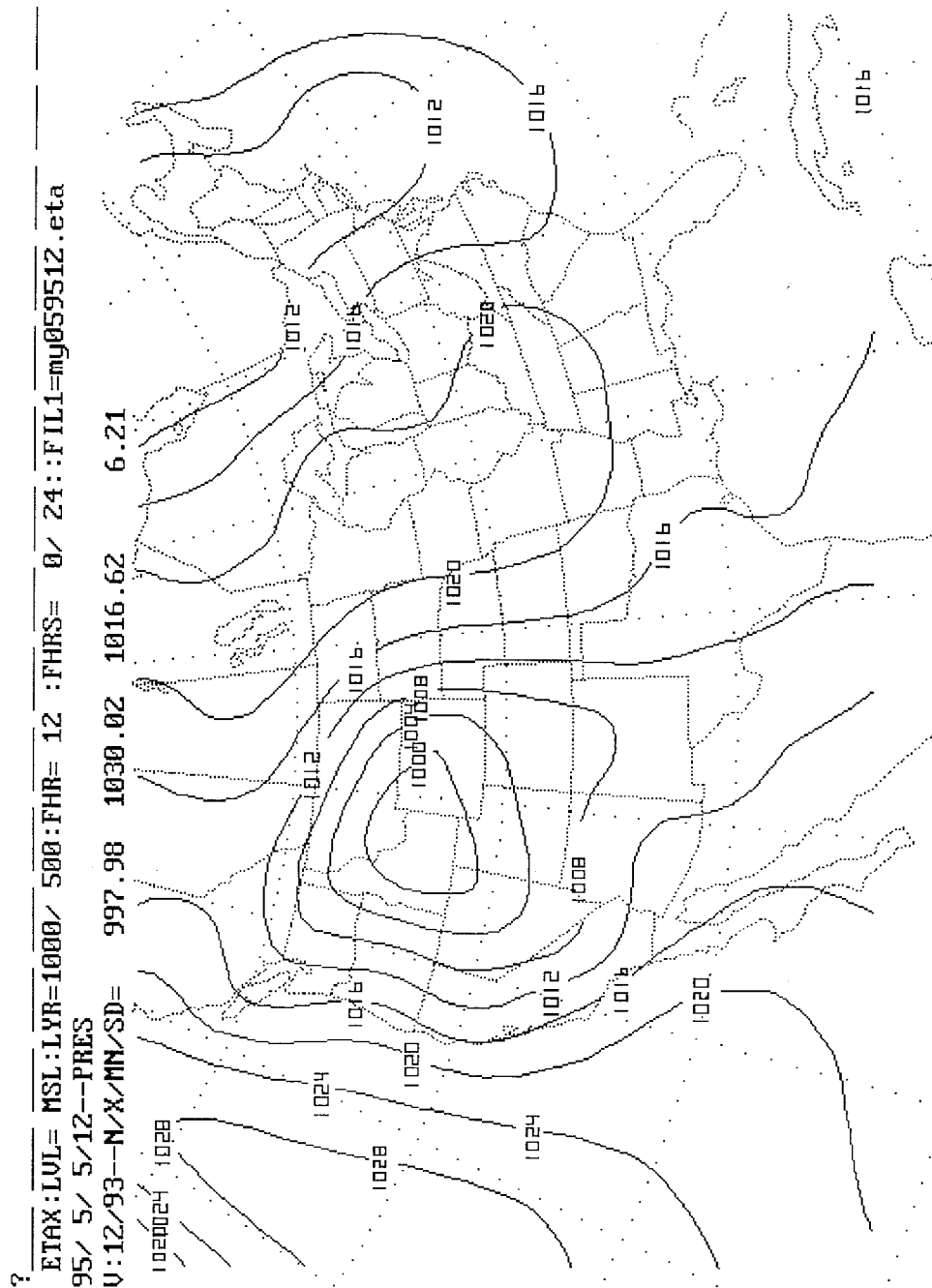
Figure 12-2: 12-hour sea-level pressure forecast, from ETA forecast model.

Figure 12-3: Four-panel forecast from NGM forecast model. Top left - 500 mb heights and vorticity; top right - 700 mb vertical velocity; bottom left - sea-level pressure and 1000-500 mb thickness; bottom right - 700 mb heights.